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# VISUALIZATION OF BRONCHIAL LESIONS USING MULTIDETECTOR CT AND ENDOBRONCHIAL ULTRASOUND (EBUS)

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**Abstract**

*Objective:* Staging of bronchial carcinoma presents a diagnostic challenge. In addition to CT scans, endobronchial ultrasound is used. The aim of this study was to compare the diagnostic accuracy of high-resolution multidetector CT (MSCT) with that of endobronchial ultrasound with respect of detection and extension of the bronchial lesions.

*Methods:* 24 patients with lesions in the central bronchial area were examined using both EBUS and MSCT. Multiplanar reconstructions (MPR) as well as virtual endoscopy (VE) were used as adjuncts in this investigation of the comparative diagnostic accuracy of MSCT and EBUS in the imaging of bronchial lesions.

*Results:* No significant difference could be established between EBUS and MSCT in detecting and extension of bronchial lesions. With both procedures, the use of supplementary techniques may be advantageous and helpful in individual cases.

*Conclusions:* When compared with EBUS, MSCT with post-processing has equally high sensitivity with regard to the visualization of malign endobronchial lesions.

*Key words:* MSCT, EBUS, virtual endoscopy

## INTRODUCTION:

Endobronchial ultrasound (EBUS) has been available as an innovative diagnostic method for a number of years, and was initially used in biopsy of paratracheal tissue. As early as 1996, Shannon and colleagues [1] showed that compared with "blind biopsies", EBUS-guided needle aspiration cytology of enlarged mediastinal lymph nodes requires fewer aspirates to achieve a comparably high diagnostic accuracy. In the case of small lymph nodes, a higher hit ratio was established. The reason given was that using the technique yielded exact and clear images of the mediastinal anatomy, including the vascular structures and the lymph nodes. At the time, Shannon used only a plain ultrasound catheter with no preceding water path. However, coupling between probe and tissue could only be achieved through close contact of the probe to the bronchial wall. Becker (1997) [2] and Miyazu [3] were the first to use a balloon filled with water to encase the ultrasound probe, allowing a 360°-view of the bronchial wall. Endobronchial ultrasound thus constitutes an innovative method for improving tumor staging of bronchial carcinomas and providing information on the morphological behavior of endobronchial tumors. The aim of this study was to compare the diagnostic accuracy of high-resolution multidetector CT with endobronchial ultrasound with respect of detection and evaluation of the extension of the bronchial lesions.

## MATERIAL AND METHODS

The cohort of this prospective study consisted of consecutive patients with suspicion of bronchial carcinoma or for follow-up of a known bronchial carcinoma. Clinical diagnosis involved carrying out an MSCT scan (model used: MX 8000, Phillips AG Hamburg). The slice thickness was 4 x 1.3 mm at 120 kV.

Subsequently, multiplanar reconstructions (MPR) in the coronal and sagittal planes were obtained as part of the study. A virtual endoscopy (VE) with surface shaded display was also performed using the MX8000 workstation. The reconstructions were done by radiologists that were not involved in the assessment process.

After giving informed consent, all patients underwent bronchoscopy for the staging to assess the local extent of the tumor spreading and the status of the mediastinal lymph nodes. They were also examined using EBUS. In each case, flexible endoscopes (Olympus) were used.

The endobronchial ultrasound (Olympus UM-BS-26R-3) device consists of a 20 MHz single-element transducer mounted on a balloon catheter. The outer diameter (including the balloon) of the endobronchial ultrasound probe measures 2.6 mm and is introduced under visual control via the bronchoscope's working channel. The balloon is then filled with water until it makes complete contact with the tracheal wall. A circular 360° vertical image of the parabronchial and paratracheal structures to the level of introduction is possible up to of a depth of 5 cm [4-6]. The ultrasound investigation was recorded on video. Figure 1 shows the bronchoscopy findings of an extramural stenosis using the ultrasound probe as well as the corresponding ultrasound and CT images.

Two experienced radiologists and a pneumologist cooperated in a blinded manner to carry out an initial assessment of axial CT images on different days. In a second step, the coronal and sagittal reconstructions of the CT data set were evaluated in cine mode and were blinded analyzed in conjunction with the virtual endoscopy which was reconstructed using the surface

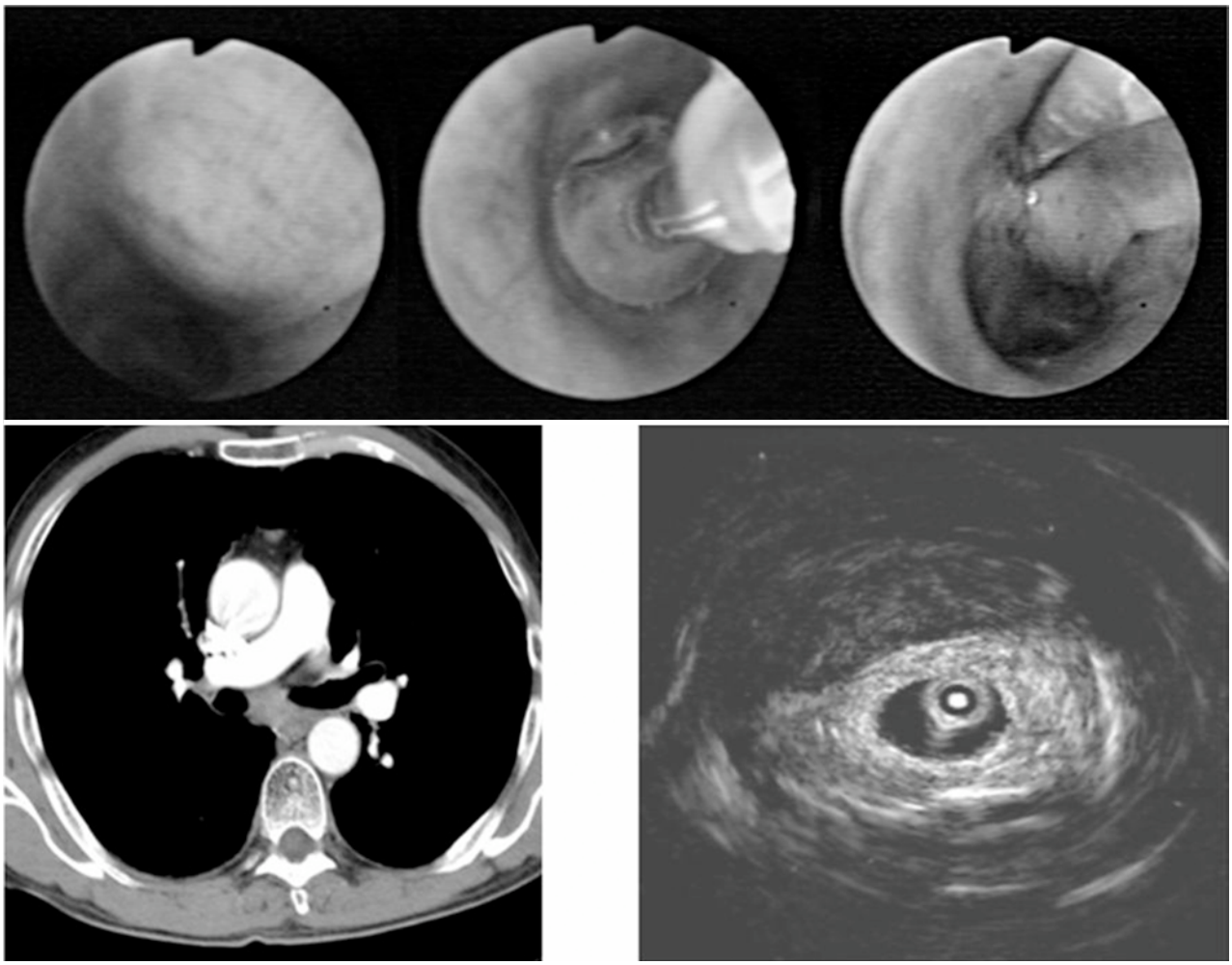

*Fig. 1.* Endoscopy (patient #2) (above): Impression of the left main bronchus due to a mediastinal mass (left). Placing of the EBUS probe (center) with the water-filled balloon catheter, biopsy extraction (right). Axial CT section on the lower left and EBUS on the lower right showing the paratracheal tumor, one pathological lymph node

shaded display method with a density threshold of -500HU. The endobronchial ultrasound images were analyzed as a video sequence. The individual cases were blinded during evaluation and taken in a random sequence. Thus, it was not possible for the evaluation of one modality to influence the evaluation of another modality.

The findings were classified in three groups:

Group 1: < 25% stenosis due to extramural impression, no lesion of the mucous membrane

Group 2: 25%- 50% stenosis, circumscribed mucous membrane lesion due to tumor invasion

Group 3: > 50% stenosis due to invasion of an exophytically growing tumor

The bronchoscopy served as a reference, whereby the endobronchial findings for all patients were verified by bioptically secured histology.

## Statistics

All statistical testing was supported by the statistical software package for the social sciences (SPSS, R. 14, SPSS Inc., Chi, USA).

For all testing bronchoscopy served as golden standard reference (GSR).

Firstly, as an indicator for the correctness of the respective group classification of the different modalities with regard to the GSR, sensitivity and specificity were calculated for each modality.

Secondly, the degree of correlation in the evaluation of the grade of bronchial stenosis with the GSR was determined for each modality (EBUS, MSCT, MSCT with MPR and VE) by calculating the kappa value.

In addition, Wilcoxon's test for matched pairs was used to test for significant differences between all pairs of two out of the three different methods (EBUS, MSCT, MSCT with MPR and VE) in the evaluation of the grade of bronchial stenosis.

## Results

Twenty-four patients in total were examined using both EBUS and MSCT in order to investigate whether MSCT is comparable with EBUS in identifying endobronchial or peribronchial malign results. The histological findings for the study patients are shown in

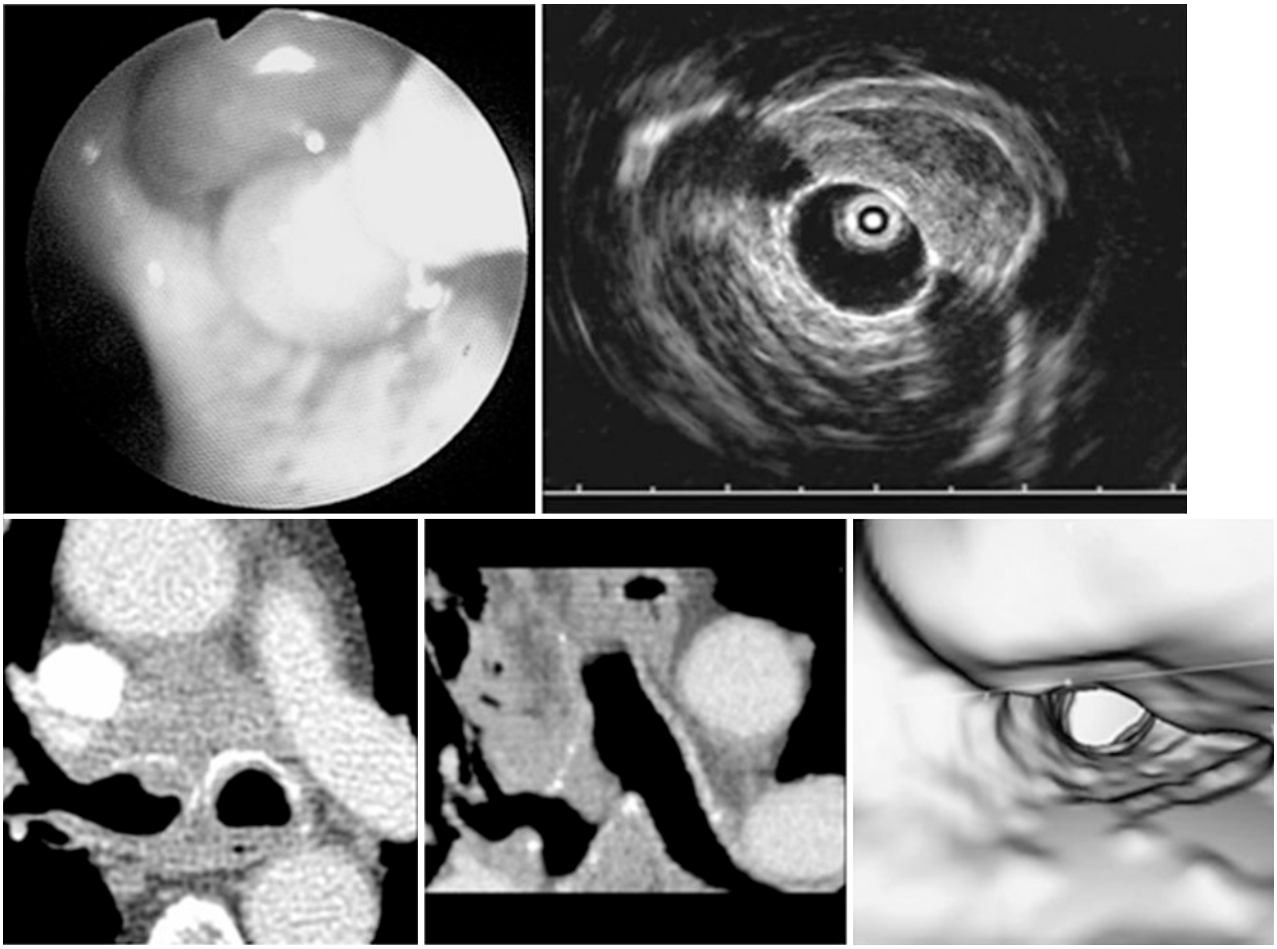

*Fig. 2.* 59-year-old patient (patient #22) with a small-cell carcinoma in the right main bronchus. Endoscopy (upper left): The exophytic tumor at 12 o'clock, using the EBUS probe. Sonography (upper right): Detection of the solid, low-echo mass. The tumor is infiltrating the bronchial wall. Primary axial MSCT slices (lower left), coronal multiplanar reconstruction (center) and virtual bronchoscopy (lower right) yield a comparable image of the tumor.

Table 1.

3 patients had a < 25% stenosis without lesion of the mucous membranes (Group 1), 7 patients presented a 25%- 50% stenosis with circumscribed mucous membrane lesion due to tumor invasion (Group 2), and in 14 patients a > 50% stenosis was diagnosed due to invasion of an exophytically growing tumor.Table 2 lists the sensitivity and specificity of the different modalities with regard to the identification of pathological changes in the different groups.

Figure 2 shows an example of an exophytic tumor with a > 50% stenosis in the different modalities.

For all degrees of stenosis, the sensitivity and specificity of MSCT was shown to be at least equal to that of EBUS, if the reconstructions were included in the assessment. Table 3 shows that most findings with axial MSCT (n=5) were underestimated, i.e. a stenosis was evaluated as more severe than actually found in the bronchoscopy, while with EBUS occasionally findings were overestimated (n=3) in comparison with the actual results.

To determine the degree of correlation for each modality, the kappa value was calculated, based on the actual results: for MSCT the kappa value was = 0.520 ($p<0.01$); for MSCT with reconstructions (MPR+VE) a kappa value = 0.691 ($p<0,001$) was established and for EBUS a kappa value = 0.568 ($p<0,001$). All these values are in the range of 0.5 and 0.7 and thus exhibit a medium correlation. Thus, MSCT with reconstructions tended to correlate best with the actual findings, followed by EBUS and, lastly, axial MSCT. There was, however, no significant difference between the different methods in the evaluation of the stenosis when using the Wilcoxon test. (MSCT vesus MSCT+ MPR+ VE: $p< 0,157$. EBUS versus MSCT: $p< 0,063$. EBUS versus MSCT + MPR+ VE: $p< 0,175$).

## Discussion:

While endobronchial ultrasound is a more invasive method than CT, it is tolerated well with good sedation and pre-oxygenation [7]. Tumor invasions characterized by thickening of the bronchial wall and moderate stenosis (25-50%) (Group 2) occurred in 7 of 24 patients in this study. Using EBUS, 5 malign infiltrations could be detected and a transmural invasion assessed. Kurimoto [8-9] was among the first to investigate the 5-layer structure of the bronchial wall using EBUS and, in an examination of 24 bronchial carcino-

*Table 1*. Histological results, localization and grade of stenosis of the findings of 24 patients (NSCLC = non small cell lung cancer, SCLC= small cell lung cancer, UL= upper lobe, ML= middle lobe, LL= lower lobe, MB= main bronchus, l= left, r= right).

| Patient number | Histological results | Localisation of the bronchial lesion | Grade of stenosis |
|---|---|---|---|
| 1 | NSCLC | UL Bronchus l | 3 |
| 2 | NSCLC | MB r | 2 |
| 3 | NSCLC | LL Bronchus l | 3 |
| 4 | NSCLC | UL Carina r | 3 |
| 5 | NSCLC | UL Bronchus l | 2 |
| 6 | NSCLC | UL Bronchus r | 3 |
| 7 | NSCLC | UL Bronchus l | 2 |
| 8 | NSCLC | UL Bronchus r | 3 |
| 9 | NSCLC | UL Bronchus r | 3 |
| 10 | Carcinoid | LL Bronchus l | 1 |
| 11 | NSCLC | MB r | 2 |
| 12 | NSCLC | LL Bronchus r | 3 |
| 13 | NSCLC | ULCarina r | 2 |
| 14 | NSCLC | UL Carina r | 3 |
| 15 | NSCLC | UL Bronchus l | 2 |
| 16 | NSCLC | MB l | 3 |
| 17 | NSCLC | MB l | 2 |
| 18 | NSCLC | LL Bronchus l | 3 |
| 19 | Carcinoid | UL Bronchus r | 1 |
| 20 | Carcinoid | UL Bronchus r | 1 |
| 21 | NSCLC | Distal Trachea | 3 |
| 22 | SCLC | MB r | 3 |
| 23 | NSCLC | ML Bronchus r | 3 |
| 24 | NSCLC | LL Bronchus l | 3 |

*Table 2*. Sensitivity and Specificity of the different modalities with respect to the endobrochial findings: a: Results of the modalities for all patients investigated with regard to the existence of a < 25% stenosis due to extramural impression or scarring (Group 1). b: Results of patients with a 25%- 50% stenosis with circumscribed mucous membrane lesion due to tumor invasion (Group 2) c: Results of patients with a > 50% stenosis due to invasion of an exophytically growing tumor (Group 3)

| | axial MSCT | axial MSCT + MPR+ VE | EBUS |
|---|---|---|---|
| correctly positive | 0 | 1 | 1 |
| correctly negative | 20 | 20 | 18 |
| false positive | 1 | 1 | 3 |
| false negative | 3 | 2 | 2 |
| Sensitivity | 0% | 33% | 33% |
| Specifitity | 95% | 95% | 86% |

a:

| | axial MSCT | axial MSCT + MPR+ VE | EBUS |
|---|---|---|---|
| correctly positive | 4 | 5 | 5 |
| correctly negative | 14 | 15 | 15 |
| false positive | 3 | 2 | 2 |
| false negative | 3 | 2 | 2 |
| Sensitivity | 57% | 71% | 71% |
| Specifitity | 82% | 88% | 88% |

b:

| | axial MSCT | axial MSCT + MPR+ VE | EBUS |
|---|---|---|---|
| correctly positive | 14 | 14 | 12 |
| correctly negative | 8 | 9 | 9 |
| false positive | 2 | 1 | 1 |
| false negative | 0 | 0 | 2 |
| Sensitivity | 100% | 100% | 86% |
| Specificity | 80% | 90% | 90% |

c:

*Table 3*. Comparison of actual findings (defined by bronchoscopy and histology) and the evaluation of findings by means of the different procedures.

| | axial MSCT | axial MSCT+ MPR+ VE | EBUS |
|---|---|---|---|
| Underestimated results | 5 | 3 | 3 |
| Correct results | 18 | 20 | 18 |
| Overestimated results | 1 | 1 | 3 |

mas, at the time found correlation with the histopathological preparation in terms of invasion and penetration depth in 23 of the 24 cases (95.8%).

The MSCT primary axial slices enabled detection of 4 tumor invasions – rising to 5 when multiplanar reconstructions and virtual endoscopy were included. In the two cases where false-positive evaluations were made in both modalities, the patients had already had surgical procedure for a carcinoma. Here, wall scarring with coagulated secretion in both modalities was falsely classified as recurrent. The only false-positive case with primary axial MSCT (in EBUS correctly negative) was likewise a recurrence-free patient with status post carcinoid. However, when the multiplanar reconstructions were taken into account, the patient could be correctly categorized as negative.

Of the 14 exophytically growing tumors with >50% stenosis (Group 3), 2 could not be adequately visualized with the ultrasound. In both patients, the tumor was situated so anatomically unfavorably that satisfactory visualization of the tumors was hindered by air artifacts arising through insufficient contact of the balloon with the bronchial wall. The deficient contact of the fluid-filled balloon with the tracheal wall led to air pockets between the balloon and the mucous membrane and thus to artifacts in the image. This is a known problem with endobronchial ultrasound, which has already been described [5-7]. In 12 patients in our study, an exophytically growing tumor with > 50% stenosis could be correctly detected using EBUS. All 14 exophytically growing tumors were detected with MSCT. Two false-positive CT cases were analyzed in the primary data, of which one was also analyzed in the reconstructions. Here, coagulated secretion was interpreted as a mass. This is a known phenomenon already described by Rapp in 1988 [10].

In the main, MSCT with reconstructions tended to correlate best with the actual findings, followed by EBUS and, lastly, MSCT with primary axial data. There was, however, no significant difference between the methods.

With regard to sensitivity and specificity, EBUS results are comparable with other investigations. In the literature, EBUS has a sensitivity of 89% and a specificity of 100 %, while in the same patients spiral CT displays a sensitivity of only 25% [11]. The most likely cause of the low CT sensitivity is the relatively large slice thickness of 5 mm. It is also known from virtual coloscopy that the sensitivity of tumor detection in virtual endoscopy varies with slice thickness and thus depends on the resolution in z direction. Cotten et al [12] likewise showed a sensitivity of only 39% for tumors of 6-9mm using single slice CT. Another study showed a sensitivity of 94% for tumors of 6-9mm using Multislice CT (MSCT) [13]. No study exists to date for the thorax in which a comparison is made of the use of endobronchial ultrasound and MSCT in the diagnosis of bronchial carcinoma.

Fischbach et al. [14] were, however, able to show that MSCT of the thorax can detect significantly more round structures in the axial sections at a slice thickness of 1.25 mm (100% sensitivity) than at 5mm (88-86% sensitivity). Multiplanar reconstructions also show a correlation between decreasing slice thickness and increasing sensitivity in the identification of mediastinal and hilar tumors [15]; in this investigation the sensitivity of 76% at 0.5 mm slice thickness falls to 68% at 5 mm slice thickness.

While air in the bronchial system is a problem for EBUS, in CT it leads to a high contrast in comparison with soft parts and allows relatively simple virtual surface reconstructions (surface shaded display). Due to the thin collimation with MSCT, stair-step artifacts are only minimally detectable. Despite the lack of opportunity for tissue extraction, virtual bronchoscopy can supply important information and offers a good anatomical overview, especially in the case of bronchoscopically impassable stenoses [10, 16, 17]. A disadvantage of virtual endoscopy is that only the endobronchial surface is visualized. Lacrosse [18] describes the bronchial wall defects simulated in VE if the thresholds for the CT densities are incorrectly selected in reconstruction. If, however, only the central airways with a threshold of -500 HU were reconstructed, these artifacts did not constitute a serious problem, as already described [19].

In addition, in the present study virtual bronchoscopy was not evaluated separately but only in conjunction with primary axial slices and the secondary multiplanar reconstructions. A number of existing studies recommend VE procedures are only assessed in conjunction with planar CT views, in order to have a better anatomical overview [16, 20] and identify potential artifacts in the VE. In the future, virtual bronchoscopy using volume-rendering techniques will potentially offer the scope to deliver information not only about endoluminal mucous tumors but also submucous and peribronchial lesions.

In this study, no significant difference was established between the methods for detecting bronchial lesions. Sonographical orientation during examination of the mediastinum using EBUS requires a lot of experience. This is due not only to anatomical complexity and the motion artifacts caused by pulsation and breath, but also to section planes that are unfamiliar to many bronchoscopists. While the section plane in the trachea still corresponds to the axial cross section in CT, in continuing its passage through the left main bronchus the image tilts increasingly until ultimately a coronal section plane and – when depiction of the upper lobe is continued – an inverse horizontal view results. Therefore, as with virtual endoscopy, a correlation of EBUS with multiplanar reconstructions from CT is highly recommendable in order to ensure a better anatomical overview.

Endobronchial ultrasound is a sophisticated method

with which the examiner can visualize the bronchial wall as well as neighboring structures such as lymph nodes and vessels. MSCT with its secondary reconstructions in 2D and 3D offers additional information by way of increasingly thinner collimation and is a noninvasive as well as operator independent method. MSCT with reconstructions is perfectly able to match the performance of EBUS in respect of many questions concerning the detection of pathological findings.

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